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CONDUCTIVE MATERIAL BASED ON CELLULOSE AND POLYANILINE FOR ACTIVE PACKAGING APPLICATIONS

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Smart packaging for food has undergone a transformation from traditional packaging consisting of the most inert interaction with food to active and intelligent packaging. Active and intelligent packaging make both food and food products safer and with better quality through a useful interaction between the packaging environment and the food to provide active food protection [1].

There are three types of intelligent systems in food packaging that are: sensors, indicators and radiofrequency identifiers. The material developed in this investigation is a chemical sensor. This type of sensor usually has nano components that give it excellent electrical and mechanical properties, along with the high specific surface area [2]. Among its applications is to detect pathogens, chemical contaminants, deterioration, alteration of the product and track ingredients or products through the processing chain [3].

In this research a conductive material was developed with the aim to obtain a smart packaging material that sensors the alteration of a food stuff product through the electrical changes caused in the developed material. To achieve this a formulation was obtained by combining the properties of nano complex gel base on cellulose and the conductive property of the oxidized aniline. The electrical impedance as answer variable allowed to determine the best process condition for obtaining the smart film.

Ionic complex gel: A colloidal crystal was obtained by creating an ionic complex with Polyhexamethylene guanidine hydrochloride polymer (PHMG) and Polyanionic cellulose (PAC). The negative charge is granted by PAC which has a higher degree of carboxymethyl substitution than carboxymethyl cellulose and can be used as a thickening agent, rheology controller, bond, stabilizer, colloidal protector and suspending agent. On the other hand, the positive charge is granted by PHMG, which has antimicrobial and fungicidal capacity [4]. A solvent was added to better distribute

the loads of the mixture. This solvent is compatible with hexamethylene isocyanide used as crosslinker agent. Crosslinking modification of colloidal particles enables a sudden increase in mechanical properties [5]. Formaldehyde was adding in the same proportion with the cross linker so that the Ugi reaction between them allows the formation of nanoparticles. The mixture was acidify with hydrochloride acid (HCl) to a pH of 3 in order to increase the diameter of the particles during the reaction.

The ionic complex when mixes with chloroform form an emulsion system. The drops formed through the emulsion generate a precipitate phase which in company with the formation of polyaniline precipitates formed the main matrix of the conductive material of this research.

Obtaining Polyaniline (PANI): aniline was oxidize to obtain emeraldine 'salt' (oxidize form of PANI), which is green and has high electronic conductivity property [6]. PANI was synthesized by chemical oxidation with the use of hydrochloric acid in the presence of ammonium persulfate in an aqueous medium (ionic complex). The synthesis of PANI took place at pH < 2.5 to achieve the addition of monomeric aniline molecules to the active chain ends [7] for the formation of PANI. Initially pernigraniline oligomer is formed sometime after aniline is in contact with ammonium persulfate. This oligomer then withdraw a proton from an aniline molecule as mechanism of oxidation of aniline, without forming a strong co-ordination bond either with the substrate / intermediate or with the final product [8]. Polymer chains grow in the oxidation state close to the protonated pernigraniline that is the reason why before obtaining the green emeraldine it was observed a blue colour.

Only the green protonated emeraldine has conductivity on a semiconductor level of the order of 10^0 S cm^{-1} as shown in the (table).

Table

Oxidized states of PANI

Type of form	Name	Colour	Conductivity [S*cm^{-1}]
Oxidized form	Polypernigraniline base	Purple	$<10^{-5}$
	Polyemeraldine salt	Green	~15

The supernatant layer after the precipitation of PANI with the emulsion ionic complex is discarded. The precipitates were mixed with a compatible polymer chosen by preliminary experimentation. As the addition of this polymer gives its own charge to the mixture was necessary to protonate the mixture once again.

To optimize the process conditions is needed to analyze the electrical impedance of the casted samples. The most important factors that causes changes in the conductivity of our samples are the concentration of the compatible polymer and the protonation of the mixture. After using our response variable to determine the best conditions to obtain the research material is planned to review and determine whether the addition of extra additives improves the properties of the material so that the casted material would has shape memory property due to a structure similar to a macro porous sponge [9] which is achieved with the evaporation of the chloroform that forms part of the micelles formed in the emulsion.

References

1. *Biji K. B., Ravishankar C. N., Mohan C. O.* // J Food Sci Technol. 2015. Vol. 52, № 10. P. 6125–6135.
2. *Vanderroost M. et all* // Trends Food SciTechnol. 2014. Vol. 39. P. 47–62.
3. *Nachay K.* // Analyzing nanotechnology. Food Technol. 2007. Vol. 61, № 1. P. 34–36.
4. *Yuanfeng P., Qiuyang X., Huining X.* // Polymers. 2019. Vol 11. P. 1283-1299.
5. *Zhang Y., Wang J., Huang Y. et al.* // Chem. 2011. Vol. 21. P. 14113.
6. *Sapurina1 I., Stejskal J.* // Polym Int. 2008. Vol. 57. P. 1295–1325.
7. *Geng Y., Li J., Sun Z. et al.* // Synth Met. 1998. Vol. 96 (1).
8. *Ravindrakumar M., Bavane G.* // North Maharashtra University, Jalgaon. 2014. P. 3.11–3.22.
9. *Liu Y., Xu K., Chang Q.* // Adv. Mater. 2016. Vol. 28. P. 7758–7767.

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BIOMIMETIC SOL-GEL MINERALIZATION OF POLYSACCHARIDES BY SILICON AND TITANIUM POLYOLATES*

Keywords: silicon and titanium polyolates, polysaccharides, biomimetic sol-gel mineralization, element-containing hydrogels, dental films.